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Can Conservation Contracts Co-exist with Change? Payment for Ecosystem Services in the Context of Adaptive Decision-Making and Sustainability

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Abstract This paper considers the ability of payment for ecosystem services (PES) programs to operate in the context of dynamic and complex social–ecological systems. Drawing on the experiences of two different PES programs in Latin America, we examine how PES institutions fit with the tenets of adaptive decision-making for sustainable resource management. We identify how the program goals and the connection to the market influence the incentive structure, information gathering, learning and feedback processes, and the structure of decision-making rights, specifically the ability to make and modify resource-use rules. Although limited in their generalizability, findings from the two case studies suggest a tension between the contractual model of PES and adaptive decision-making in natural resource systems. PES programs are not inherently decentralized, flexible management tools, as PES contracts tend to restrict decision-making rights and offer minimal flexibility mechanisms to change resource-use practices over the duration of the contract period. Furthermore, PES design and flexibility is heavily dependent on the goals and mission of the buyer and the respective market. If PES is to facilitate sustainable resource management, greater attention is needed to assess how the institutional design of the PES contracts influence the motivation and capacity of participants and program officers alike to adaptively manage the respective resource systems.

Keywords Adaptive management · Latin America · Ecosystem services · Institutions

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Introduction

This paper examines the potential of payment for ecosystem services (PES) to facilitate adaptive decision-making in dynamic social-ecological systems in the Global South. In resource management and sustainable development, scholars and practitioners increasingly recognize that social–ecological systems are not stagnant and that successful resource management depends on the ability of individuals and organizations to learn from current and projected socio-economic and ecological conditions, act upon this knowledge, monitor outcomes, and take action once again (Walker et al. 2002; Sayer and Campbell 2004; Armitage 2005; Folke et al. 2005; Grothmann and Patt 2005; Ostrom 2005; Scarlett 2013). Policies and programs,

therefore, can no longer presume to maintain a static status quo, but rather, need to support decision-making processes that enable resource users and managers to understand and appropriately address change (Sayer and Campbell 2004; Folke et al. 2005; Scarlett 2013).

PES expert, Sven Wunder, proposes that PES programs are a flexible and "highly adaptive management tool" for conservation (Wunder 2013, p. 230). While not a panacea, PES proponents suggest that the use of direct incentives linked to conditional contracts is an innovative means to promote specific resource management activities or produce desired environmental services that would otherwise be undervalued and under-produced. Proponents argue that as a voluntary, decentralized policy tool, PES may be more effective than top-down command and control conservation policies or vaguely defined integrated conservation and development projects (Wunder 2005, 2013; Engel et al. 2008).

The growing use of contracts poses questions for how PES programs, and their respective contractual agreements, fit or conflict with decision-making processes for sustainable resource management. Scholars have assessed the institutional requisites for PES programs (Wunder et al. 2008; Clements et al. 2010; Vatn 2010), examined the potential for PES programs to provide environmental, economic, and social benefits in resource-dependent communities (Landell-Mills and Porras 2002; Zbinden and Lee 2005; Kosoy et al. 2008; Pagiola et al. 2008; Milder et al. 2010; Jindal et al. 2012; Mahanty et al. 2013; Greiner and Stanley 2013; Tacconi et al. 2013), and questioned the commodification of nature for conservation in the Global South (Liverman 2004; Corbera et al. 2007a, b; Igoe and Brockington 2007; Sullivan 2009; Kosoy and Corbera 2010). Recently, given the development of REDD+ pilot initiatives, scholars and practitioners have devoted greater attention to the use of contracts in conservation, particularly emphasizing the importance of transparency and free and prior consent (Larson et al. 2010; Lyster 2011). Few studies, however, have assessed whether PES is in fact, a suitable tool for flexible resource management.

In Latin America, various PES programs have been implemented as a means to protect watersheds, sequester carbon, and conserve biodiversity (Corbera et al. 2007a, b; Kosoy and Corbera 2010; Muradian et al. 2013). In its application, PES programs vary depending on the buyer, the seller, the connection to a market, the type of service to be provided, the type of incentive, and the pay-off conditions (Engel et al. 2008; Muradian et al. 2010; Tacconi 2012). In some cases, PES arrangements are "user-financed" by a buyer who is the actual user of the environmental service. These services may or may not be purchased via an actual market where competitive trading exists (Wunder 2013). In other cases, the programs are "government-financed," referring broadly to programs in which governments, international donors, or NGOs buy the service on behalf of others (Engel et al. 2008). In both user- and government-financed arrangements, intermediaries frequently coordinate the provision and PES and stipulate the rules to ensure service provision (Muradian et al. 2010).

This paper draws from two experiences in Ecuador and Colombia to examine how PES conservation contracts interact with the tenets of adaptive decision-making and sustainable resource management. The PES programs in Ecuador and Colombia exemplify two different types of PES arrangements commonly found in the Global South (Pagiola et al. 2005; Engel et al. 2008; Wunder and Albán 2008; Farley et al. 2011). In Ecuador, a "user-financed" arrangement paid farmers to afforest degraded lands to create carbon offsets. From 1993 to 2002 Forests Absorbing Carbon Dioxide Emissions (FACE), a project of the Dutch Electricity Board, provided financial support to an Ecuadorian company, Programa Face de Forestación del Ecuador S.A. (PROFAFOR), to promote pine plantations as a means to create carbon offsets for the carbon market and participate in the Clean Development Mechanisms (CDM) emerging out of the Kyoto Protocol. While this study focuses on plantations in southern Ecuador, the program worked across the Ecuadorian highlands, accounting for almost half of the reforestation efforts occurring in Ecuador during this time period (Wunder and Albán 2008).

In Colombia, a "government, specifically a donor-financed" arrangement, supported forest protection for watershed conservation by providing in-kind incentives to smallholder farmers to cover the start-up costs to switch to more sustainable dairy farming, or "silvopastoral" practices. Silvopastoral practices that include planting live fences and dispersed trees in pastures, protecting riparian regions, and creating fodder banks have been promoted across Latin America and have shown to provide ecological and economic benefits once start-up costs have been covered (Nair 1985; Dagang and Nair 2003; León and Harvey 2006; Wunder 2006; Pagiola et al. 2007; Murgueitio et al. 2011). Drawing on a silvopastoral PES model supported by the World Bank and the Food and Agricultural Organization (FAO), a consortium of NGOs sought to extend the model to support livelihood development, sustainable dairy farming, and watershed protection among poor smallholder farmers in Colombia's eastern Andes.

The programs are not intended to be directly comparable and are limited in their generalizability. The case studies, however, provide insights into the potential of PES to act as a tool for flexible resource management. Furthermore, the different program types serve to identify how distinct institutional structures influence the adaptive decision-making processes of local resource managers, specifically

rural landholders, and of program officers charged with implementing said conservation programs. Drawing from literature on decision-making and resource management, we focus on how (i) the incentive structure, (ii) information exchange mechanisms, and (iii) rule-making rights and flexibility mechanisms influence the capacity of resource users and program managers to experiment, learn, and respond to new information or changing conditions. The findings suggest that PES is not necessarily a decentralized, flexible tool for resource management, and that "user-financed" programs for carbon sequestration may be particularly challenged to act as tools for adaptive decision-making.

Contributions from the Literature on Decision-Processes for Sustainable Resource Management

Faced with the challenges of managing dynamic social and ecological systems, natural and social scientists in the field of sustainable development increasingly support the use of flexible, or "adaptive", resource management models (Berkes and Jolly 2001; Folke 2006; German et al. 2006; Celleri and Feyen 2009; Williams and Brown 2014). Initially conceived as an explicitly experimental and decentralized method to address uncertainty in resource management, the concept of adaptive management has evolved to broadly represent adaptive decision-making processes that support experiential learning and feed-back based management (Holling 1978; Rist et al. 2012; Williams and Brown 2014). Although few empirical studies have examined the impact of adaptive management, as initially conceived, a recent review by Rist and colleagues (2012) found that out of the 15 studies reviewed, nine demonstrated that adaptive management generated a positive value. Furthermore work in agricultural adoption, agroforestry systems, and common-pool resource management consistently supports the broader concept of adaptive decision-making as studies find that success often depends on the ability of resource managers, including local resource users, to experiment, learn, and make adjustments accordingly (Berkes and Jolly 2001; Hagmann and Chuma 2002; Mercer 2004; Armitage 2005).

In his review of the key elements that support sustainable resource management, Lambin (2005) focuses specifically on the importance of decision-making processes. He argues that sustained resource management demands that decision-makers have the information to understand and assess the resource system being governed, the motivation to take actions to respond to information and sustainably manage the system, and the capacity to make and implement management decisions (Lambin 2005, pp. 178–179).

The challenge for policymakers is how to design conservation policies and programs that provide information, motivation, and the capacity for resource managers to adaptively manage their resource systems. Previous studies of PES's impact on sustainability and capacity-building have largely focused on access to assets (van de Sand 2012; Mahanty et al. 2013; Tacconi et al. 2013). While assets are important in enabling decision-making processes, work in common-pool resource management, agricultural adoption, adaptive management, behavioral economics, and social psychology suggest that institutional factors may also be critical in determining if resource managers have the motivation, information, and capacity to address changing social and ecological conditions (Bandura 1977; Ostrom 1990; Ajzen 1991; van den Bergh et al. 2000; Hagmann and Chuma 2002; Dietz et al. 2003, Grothmann and Patt 2005; Vignola et al. 2010). Specifically, said scholarship suggests greater consideration of how a PES program's incentive structure, information exchange mechanisms, and rule-making rights and flexibility mechanisms, influences the decision-making capacities of the participants and program officers to try a new management practice, monitor the results, and make adjustments accordingly.

Incentive Structure

In natural resource management, a critical question is what drives, or incentivizes, resource managers to sustainably manage their resource systems. In PES programs, the motivation to change behavior and produce the desired ecosystem service is assumed to come from a direct economic incentive that is further supported by a conditionality clause or set of sanctions to be applied if the desired resource-use behavior is not performed. While PES proponents recognize that sustainable resource management may depend on other factors, including an understanding of the problem and ability to resolve it, proponents contend that in many cases, education is not sufficient and that an economic incentive is needed to motivate local land managers to conserve their resource system or provide an ecosystem service (Engel et al. 2008).

Work in sustainable resource management often concurs with the argument that sustainability depends on conservation practices or alternatives that are economically viable for resource users (Bromley 1992; Wells 1992). Research in psychology, agricultural adoption, and economics, however, questions the role of direct incentives, particularly external incentives, in motivating sustained behavioral changes. Work in these fields suggests that economic incentives paired to conditional contracts may produce only short-term behavioral gains with unintended long-term consequences (Cardenas et al. 2000; van den Bergh et al. 2000; Hellin and Schrader 2003; Lambin 2005; Grothmann and Patt 2005; McGinty et al. 2008; Van Hecken and Bastiaensen 2010; Vignola et al. 2010).

Agricultural adoption studies indicate that economic incentives may serve to motivate initial adoption of a new practice, but that the motivation and capacity to continue to experiment, adapt, and sustainably manage a resource system may depend on a variety of factors that include the farmer's perception of the resource, information about the resource functioning, technical support for new management practices, and perceived capacity to address changing conditions (Bunch 1982, 1999; Giger 1999; Hellin and Schrader 2003; McGinty et al. 2008; Calle et al. 2009; Van Hecken and Bastiaensen 2010; Vignola et al. 2010). More troubling, work in behavioral economics and resource management has found that direct incentives can, at times, build dependency and thwart farmers' intrinsic motivation to actively manage their resource systems (Frey and Jegen 2001; Hellin and Schrader 2003; Clements et al. 2010; Vatn 2010).

Information Exchange Mechanisms

Lambin (2005) and others (Dietz et al. 2003; Berkes and Turner 2006; Celleri and Feyen 2009; Crespo et al. 2011) note that successful resource management depends on information about the past and present state of the environment and ecosystem functioning, the ability to detect human perturbations, and an understanding of the socio-economic and ecological values of the system. In designing PES programs, scholars have focused on understanding how the ecosystem functions to provide a desired ecosystem services (Stickler et al. 2009; Pattanayak et al. 2010; Bullock et al. 2011), and how to monitor for additionality in service provision (Ferraro 2011; Gibbons et al. 2011; Derissen and Quaas 2013). Less attention has been given to the role of local knowledge of ecosystem services and their function in the broader socio-ecological systems (Clements et al. 2010; Petheram and Campbell 2010).

Proponents of adaptive resource management often assert that sustainability depends on a more holistic management approach that includes recognition of local knowledge, provides opportunities for social learning, and supports information exchange between local resource users and higher level decision-makers (Holling 1978; Gordon et al. 2001; Hagmann and Chuma 2002; Berkes et al. 2003; Folke et al. 2005; Armitage et al. 2008). Among other benefits, social learning and information exchange between decision-makers has been found to motivate resource users to address deteriorating resource systems (Hagmann and Chuma 2002; Vignola et al. 2010; Visseren-Hamakers et al. 2012), and enable higher-level decision-makers to better target a conservation project to specific social and ecological contexts (Smith and Scherr 2002; Petheram and Campbell 2010).

Rule-Making Rights and Flexibility Mechanisms

Ultimately, even with information and motivation, sustainable resource management may be limited if resource managers lack the capacity to make or modify management rules (Ostrom 1990; Schlager and Ostrom 1992; Dietz et al. 2003; Sayer and Campbell 2004; Lambin 2005). In her work on successful common-pool resource management arrangements, Ostrom (1990) proposed a set of design principles found in successful resource systems. The ability of resource users to make and modify resource management rules is a core component of these principles.[1]

While Ostrom's design principles originally addressed communally managed systems, the ability of local resource users to make rules regarding the day-to-day management of their resource systems, and make modifications in response to changes in said systems is supported in a variety of resource management contexts. Scholarship on resource management and agricultural adoption consistently finds that when resource users perceive the capacity to make decisions about day-to-day land-use activities, and set management priorities, resource users are more likely to adopt new management practices and take actions to sustain their resource systems (Hagmann and Chuma 2002; Hellin and Schrader 2003; Schlager and Ostrom 1992; Gibson et al. 2005; Pagdee et al. 2006; Persha et al. 2011; Porter-Bolland et al. 2012). On the flip side, economists, psychologists, and political scientists caution that if local resource managers lack the authority to make site-level decisions, they may fail to consider the impacts of their resource-use activities, and external regulations could potentially "crowd out" the motivation to sustainably manage their resource systems (Cardenas et al. 2000; Frey and Jegen 2001; Ostrom 2003; Engel et al. 2008; Clements et al. 2010; Vatn 2010).

Rules that restrict the ability to modify program goals, or management practices will limit the capacity by which individuals and organizations can respond (at least formally) to new information or changing conditions (Lambin 2005). Furthermore, institutional designs that depend on external managers to initiate or modify rules may fail to recognize and respond to local dynamics (Tendler 1997; Scott 1998).

In PES arrangements, conservation contracts stipulate the rule-making rights and processes by which new management practices may be created or modified. Although contracts are assumed to be negotiated agreements between the buyer and the seller, it is questionable the degree to

[1] Specifically Ostrom's (1990): Principle 2 *Congruence between appropriation and provision rules and local conditions,* Principal 3 *Collective-choice arrangements*, and Principal 7 *Minimal recognition of rights*.

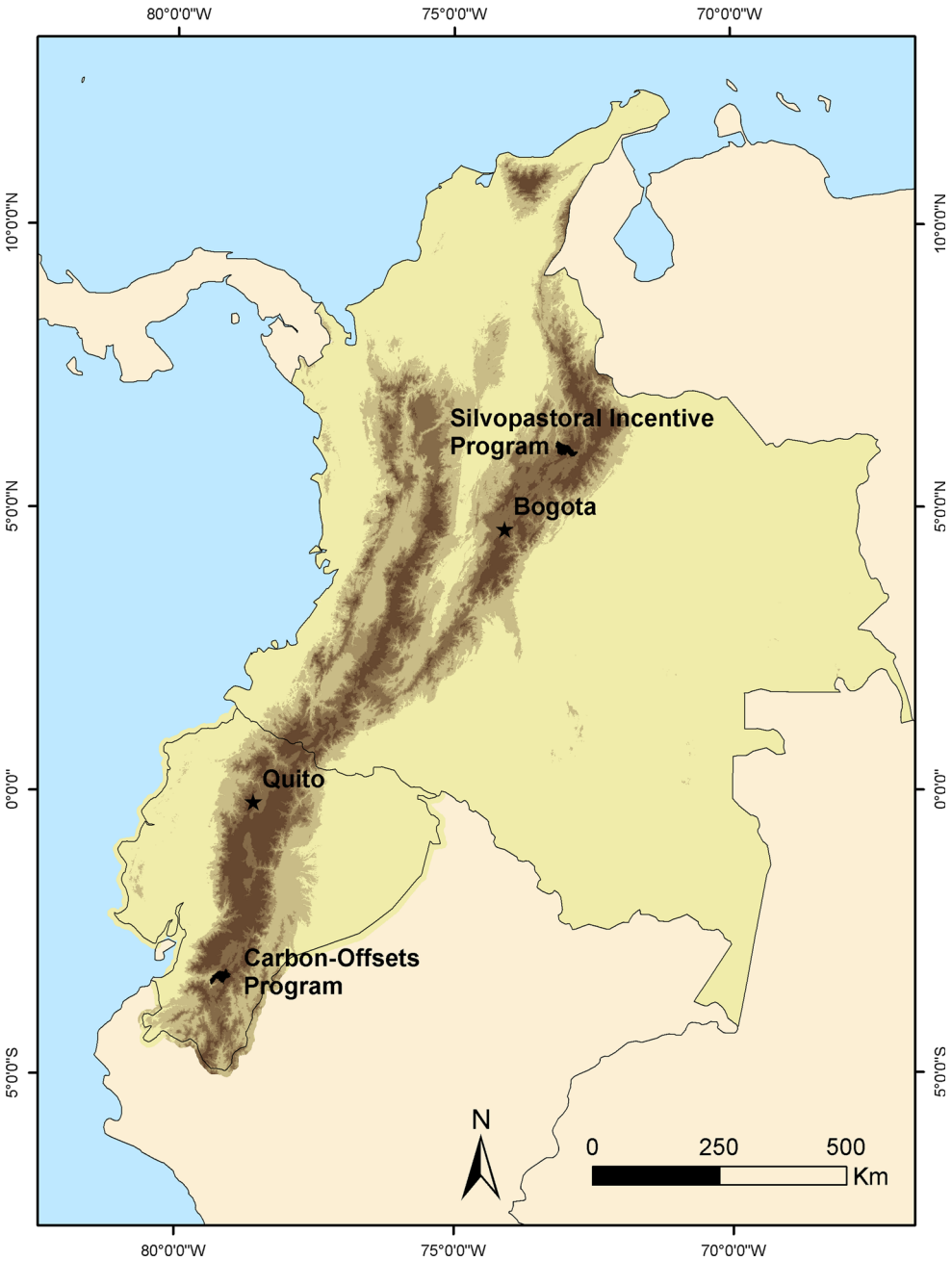

Fig. 1 Map of study areas

which participants, particularly rural farmers, influence the initial set of resource management rules, and their capacities to make modifications (Larson et al. 2010; Lyster 2011; Wunder 2013).

Methods

Study Sites

In Ecuador, we chose to study the carbon offsets program because it was one of the first PES programs of its kind and offered an opportunity to examine the longer-term impacts of a payment program. Although several studies were conducted during its initial years of operation (Albán and Argüello 2004; Wunder and Albán 2008), the program had received little attention now that it was approaching the end of the initial contract period.

In Colombia, the study focuses on a silvopastoral program implemented by Fundación Natura (FN), a Colombian NGO, to protect forests in the River Guacha watershed in the eastern Andean mountain range. We chose to study the FN silvopastoral program based upon conversations with The Nature Conservancy regarding examples of PES

models that aim to support conservation and livelihood goals in biodiversity hotspots. In addition, FN program managers expressed desire to understand the social impacts and sustainability of their program.

Figure 1 shows the study areas for the carbon offset program in Ecuador and the silvopastoral incentive program in Colombia. Our study focuses on individual contracts signed in the county of Nabón, province of Azuay, in the southern highlands (see Fig. 1). We selected to work in Nabón as the PROFAFOR program had not been studied in the southern highlands and the study complimented work by our colleagues at the University of Cuenca that were examining the hydrological impacts of pine plantations in the region.

Nabón is a relatively poor region of Ecuador; the majority of the population depends on agriculturally based activities and approximately 93 % of the population lives in poverty (SENPLADES 2010). In Nabón, PROFAFOR signed contracts with individual *mestizo* farmers (of mixed Spanish and Indigenous descent) to plant pine plantations located between 2,770 and 3,350 masl on lands that were previously covered by páramo, an Andean grassland ecosystem.

In Colombia, the study focuses on activities in the River Guacha watershed. The River Guacha watershed is a conservation priority in the East Andes as it forms the core of the "Oak Corridor" that covers approximately 10,730 km^2 and contains the last remnants of the Colombian oak (*Quercus humboldtii*), and the endemic and endangered flora and fauna (Solano et al. 2005). The study of the FN silvopastoral program was implemented in two municipalities: Belen, Boyacá and Encino, Santander (Fig. 1). This region consists of highland farming communities located between 2,500 and 3,000 masl. FN chose this region because of its ecological value, the high poverty levels of the residents, principally *mestizo* farmers (of mixed Spanish and indigenous ancestry), and the conflict that their small-scale potato and dairy farming presented for watershed and biodiversity conservation in the region (Solano et al. 2005).

Data

Data on the design and implementation of the carbon offset program in Ecuador were gathered via fieldwork in the region, and published and gray literature on the program (Albán and Argüello 2004; Wunder and Albán 2008). Fieldwork June–August 2011 included interviews with the PROFAFOR program director and extension agents, structured interviews with participating farmers, field observations of the pine plantations, a review of PROFAFOR program documents, and attendance at a county-level meeting on the plantations. In Nabón, PROFAFOR signed contracts with 12 beneficiaries. We interviewed five of these beneficiaries who had signed contracts from 1997 to 1999.

Data for the Colombian silvopastoral program were gathered via fieldwork and secondary documents from non-governmental organizations working with the program.[2] Fieldwork conducted July–September of 2009 included interviews with program specialists (project coordinators and extension agents), farm visits, and a participant questionnaire administered to project participants. The program began with 23 participants (2006–2009), and in September 2009 expanded to include approximately 60 new participants. Twenty-one of the initial 23 participants were interviewed in August 2009, just after completing their 3-year contracts. In September 2009, an additional questionnaire was administered to 54 of approximately 60 new participants that signed contracts in the end of August.

In both case studies, interview questions to program officers and governmental personnel asked about the origin of the program and its mission, the creation of the conditional contracts and program rules, their perceptions of the viability of the program and recommendations for improving the success of their respective programs or similar programs. Participants were asked about their motivations for participation, their ability to make land-use decisions, perceived benefits and costs from participation, the perceived legitimacy of the contracts, and their satisfaction with the program.

Findings

Table 1 shows the design characteristics of the two programs. The following findings describe the application of the distinct PES programs and the subsequent responses to changing local conditions. For each of the PES programs, we first describe how the program was applied with respect to the incentive structure, monitoring and information exchange mechanisms, and decision-making rights to make and modify resource-use rules. We then discuss new information or unforeseen challenges that participants and program officers in each program encountered, and describe the responses of participants and program officers to these changing social and ecological conditions.

Carbon Offsets Program, Ecuador

Program Application: Incentives, Information Exchange, and Decision-Making

In Nabón, PROFAFOR asked landowners to sign contracts in which they agreed to establish a lien on their lands and

[2] In addition, Luis Mario Cárdenas Camacho previously worked for FN and helped coordinate parts of the silvopastoral project.

Table 1 Comparison of PES program designs

	Carbon offsets, Ecuador	Silvopastoral incentives, Colombia
Buyer	FACE, Netherlands	Consortium of donor foundations
Implementing organization	PROFAFOR	Fundación Natura
Seller	Rural landowners with title and at least 50 ha of degraded lands	Rural landowners with de facto titles, forest, and at least 2 ha of pasture lands
Ecosystem service	Carbon sequestration	Watershed protection
Payment	Payments to cover 75 % of initial planting and maintenance costs Farmers retain rights to intermediary timber products Farmers receive 70 % of income generated from final harvest.	3-years of investment in materials and technical support to switch to silvopastoral practices
Contract duration	20–99 years	3–5 years
Conditionality clause	Full payment for plantation costs depends on a successful survival rate of the plantation Failure to maintain the trees or follow the technicians' management plans to result in thousands of dollars in fines and reimbursement for payments received	Failure to maintain in trees and forests to result in repayment of the investment made in their farms (approximately 1,444 $US per ha)
Application of conditionality clause	Forests monitored regularly. Contracts had been canceled for failure to comply, but limited ability to retain fines (Wunder and Albán 2008)	Contracts have been terminated, but no farmer had been asked to repay investment

maintain the pine plantations for a minimum of 20 years (some farmers were asked to extend their contracts to 99 years). Participants planted a total of 1,301 ha of pine, with median plantation size of 57 ha. Most participants combined agriculture work with jobs in the service industry, and prior to participating in the program, had been using the lands for extensive grazing. The pine plantations represented 50–90 % of the participants' total landholdings.

Similar to many PES programs, the carbon offsets program used economic incentives to motivate farmers to convert their degraded pasture lands to pine plantations. The first incentive was given at the beginning of the program. PROFAFOR covered 75 % of the initial planting and maintenance costs, and provided technical support and pine management workshops for the participants. The farmer retained all rights to the non-timber forest products and intermediary forest products from pruning and thinning. The largest incentive was given at the end of the 20-year cycle, when PROFAFOR guaranteed the farmer 70 % of the profits from the final timber sale. PROFAFOR retained rights to the carbon fixed by the pine plantations and received 30 % of the final timber profits, assuming that the land was not replanted at the end of the contract period (Profafor n.d.).

In order to ensure compliance, farmers were paid 80 % of their total compensation for the pine plantations at the start of the contract, and the remaining 20 % 3 years later, provided a successful survival rate of the plantation. In addition, all program benefits were provided on the condition that the farmers followed the maintenance guidelines stipulated by the PROFAFOR technicians, prohibited grazing on the plantation lands, and protected their forests from fire. Failure to maintain the trees or follow the technicians' management plans could result in thousands of dollars in fines and reimbursement for payments received (Wunder and Albán 2008). In Nabón, however, there were no reports of fines.

Information gathering mechanisms largely focused on assessing carbon sequestration and monitoring the plantations. Prior to choosing a region, PROFAFOR gathered information to determine whether the region was suitable for carbon sequestration, had relatively low opportunity costs, and a market for timber products (Albán and Argüello 2004; Wunder and Albán 2008). Pine was chosen for many of the plantations given its relatively rapid growth rate and its widespread use in the highlands. It also complimented the reforestation efforts of the Ecuadorian government (Albán and Argüello 2004; Wunder and Albán 2008). PROFAFOR worked with SGS, a global carbon certification company, to guarantee the provision of carbon sequestration credits for the life of the contract (Albán and Argüello 2004). Plantations were monitored by program technicians at least once a year during the first 3 years and then again in years 5, 7, and 10. Information was exchanged with participants largely through the instructions provided by the PROFAFOR extension agents during their site visits and a set of workshops during the first few years on plantation management.

The right to make decisions about the day-to-day operations of the plantation, contract conditions, and modifications to the contract conditions was made by PROFAFOR officers. In addition to setting the contract duration and compensation stipulations, PROFAFOR technicians decided the plantation species and planting techniques, when it was appropriate to prune or thin the trees and the harvesting schedule. According to the contract, it was possible to revise management plans in year 10 although no farmers in Nabón reported any modifications. Farmers were permitted to sell their land; however, the PROFAFOR contract remained tied to the land.

Responses to New Information and Changing Conditions

At the time of our fieldwork, the plantations were 12–14 years old. In that time, changing conditions and new information challenged the ecological and economic viability of the program and its respective practices. First, ecologically, there have been growing concerns regarding the use of pine plantations in Ecuador (and elsewhere) as conservation priorities have focused on the importance of native ecosystems, and watershed protection (Hofstede et al. 2002; Jobbágy et al. 2006). In interviews, Nabón county officials stated that the county's plantation programs now only used native species. In a community meeting at the county seat in Nabón, farmers expressed concerns regarding the existing pine plantations in the region, claiming that the trees dried up the watersheds. The science to support these complaints is complex (Hofstede et al. 2002), but studies of pine plantations in the Ecuadorian highlands have found that pine trees may decrease water retention and reduce water yield by as much as 50 % compared to natural catchments due to higher transpiration, interception, and subsequent evaporation (Farley et al. 2004; Buytaert et al. 2007; Crespo et al. 2010, 2011).

Second, the pine plantations in Nabón have generally failed to thrive. In an interview, the director of PROFAFOR noted that pine was ill-suited to the poor soils in the region, and that the economic viability has been further compounded by limited demand and low-market value. In interviews with the program participants, many expressed dissatisfaction with the program, noting the poor conditions of the trees and uncertain profits. According to PROFAFOR's planning documents, farmers could expect to earn approximately US$ 480 from pruning and thinning activities in the first 15 years. Farmers in Nabón, however, stated that they had yet to receive economic or in-kind benefits from the plantations. Participants noted that the funds received from PROFAFOR covered the initial plantation costs, but did not cover the pruning costs and several responded that they had not completed pruning because they lacked funds. Future economic benefits also looked bleak as forestry officials in the region estimated that farmers could expect to earn US$ 1 per tree.

Finally, the payments received for carbon sequestration have not proven economically viable for PROFAFOR. The director stated that the market price for carbon was lower than expected and the price did not cover the payments to the participants and the transaction costs of recruiting participants and monitoring the plantations. Counter to its initial expectations, PROFAFOR was not able to sell many of its carbon credits under the Kyoto CDM as most projects were planted before the cut-off date. In addition, the dollarization in Ecuador increased implementation costs (Wunder and Albán 2008).

Findings of the participants' and the PROFAFOR program's responses to the unexpected economic and ecological conditions demonstrated their limited the adaptive decision-making capacities to modify plantation practices. In interviews, participants consistently stated that the initial plantation payments and the expected profits from future timber sales motivated them to plant pine on their properties. Despite growing concerns regarding the ecological suitability of pine, the participants' greatest concerns revolved around the condition of the trees and their economic viability. Only one participant, however, had any information on how the timber would be harvested, where it would be sold, and potential prices for that timber. Rather, participants stated that they relied on PROFAFOR to instruct them on the timber harvesting process and marketing.

A frequent critique made by participants was that the contract conditions did not allow them to make land-use changes given the poor condition of their trees. Only one participant considered the contract to be just, while others criticized the inability to make modifications in response to new economic, ecological, and familial conditions. Two participants specifically mentioned that they would like to be able to graze cattle in the forests in order to gain greater benefits from the land, but were unable to do so because of contract conditions.

PROFAFOR tried to respond to new ecological information regarding pines and the market viability of the plantation programs, but as an intermediary organization for sales to the carbon market, the organization had limited decision-making capacity. According to the program director, PROFAFOR worked to incorporate native species on the newer plantations. Initially, PROFAFOR collaborated with Ecopar, a research organization started by the University of Amsterdam with funding from FACE to study the use of native species, however, that partnership ended in 2002 (Albán and Argüello 2004). PROFAFOR continued to experiment with native species on newer plantations, but the program director stated that it was difficult to find species that are resilient in the highland

conditions and the results have generally been unsuccessful.

Likewise, PROFAFOR has been limited in its ability to respond to poor market conditions for the pine plantations and the unexpectedly low price of carbon. As of 2009, all carbon credits had been sold on the carbon market (Profafor n.d.). Thus, while PROFAFOR was able to change practices on new plantations, it is committed to the original management plans in previously planted sites that have sold their carbon offsets. Ultimately, in response to low market prices for carbon credits and high implementation costs, the director stated that PROFAFOR decided to discontinue the program and is no longer contracting any new plantations. While it maintains the original contracts, the organization has diversified its portfolio of services in response to new opportunities in forest management.

Silvopastoral Incentive Program, Colombia

Program Application: Incentives, Information Exchange and Decision-Making

In the River Guacha, FN worked with approximately 80 individual farmers to implement conservation measures on their lands. In order to be eligible to participate in the program, a farmer was required to hold de facto title to land in the designated watershed region, have forest, and have at least two ha of pasture lands (Giraldo et al. 2012). Most farmers in the region held approximately 5 ha in pasture and 1.5 ha of forest (Hayes 2012). Each participant was initially asked to sign a 3-year contract in which the farmer agreed to conserve the remaining forests on his/her lands, and continue with the silvopastoral practices by planting and maintaining the live fences and dispersed trees in his/her pastures.

Similar to the PROFAFOR incentive structure, FN also used an incentive and conditionality clause to motivate farmers to experiment with the silvopastoral practices and conserve their forest remnants. FN provided in-kind payments to cover the initial start-up costs and compensate them for their participation. The in-kind payments included several applications of fertilizers to recuperate pasture lands, fence posts, barbed wire, and tree seedlings. In addition to the economic incentives, FN also provided extension support for 3 years and workshops on specific silvopastoral practices. During the implementation process, program technicians spent 2–3 weeks a month in the communities, and a local resident was hired as an extension agent to work with the farmers and maintain program presence.

According to contract conditions, if a participant did not maintain their trees and forests, the participant would have to pay back all of the investment made in their farms (approximately 1,444 $US per ha). At the time of the fieldwork, program extension agents reported that no farmer had been monetarily penalized for non-compliance, however, several had been asked to leave the program for failing to meet contractual obligations.

Information exchange and monitoring mechanisms involved a preliminary analysis of the ecological characteristics of the region, collaboration with silvopastoral specialists, a variety of learning activities to engage with the program participants, and field studies to assess the ecological impacts. Prior to starting the program, FN identified target communities based upon a forest cover analysis of connectivity in the watershed. In designing the silvopastoral program, FN worked with silvopastoral specialists to define the land-use options and select the native tree species. Program officers commented on the challenges of selecting native tree species given the relative dearth of information on native trees in the region and lack of availability. Ultimately, the program initially selected to work with Elderberry (*Sambucus peruviana*) and Alder (*Alnus acuminata*).

Information exchange with the participants included workshops, working one-on-one with technicians, and farmer-to-farmer field trips. In order to increase adoption of the silvopastoral techniques, program extension agents encouraged farmers to share their experiences with others and organized exchanges with other farmers using the conservation techniques.

To monitor the livelihood and ecological impacts of the program, FN extension agents visited the farms on a regular basis to ensure that farmers were maintaining the live fences and forest lands, and assessed changes in milk production on the improved pasture lands. Although met with varied success, participants were encouraged to keep a log of their daily dairy production so that they could monitor changes in output. FN monitored the ecological impacts using satellite imagery to assess changes in forest connectivity and by gathering biophysical data on biodiversity.

Decision-making regarding contract provisions and program practices involved participants, silvopastoral specialists, and program officers. According to interviews with FN staff and participant farmers, the decision to start with a short-term 3-year contract was based upon input from interested participants. In addition, in order to encourage ownership of the silvopastoral techniques, program technicians stated that they provided a portfolio of land-use options to each farmer, and worked with individual participants to select the specific practices for their farm.

The short-term contracts did not allow for any formal means by which participants or program officers could modify the terms. Farmers were expected to comply with

the forest and tree conservation commitments for the duration of the contract. After the initial 3-year period, farmers were asked if they wished to continue with the program and new contractual conditions were considered.

Responses to New Information and Changing Conditions

At the time of the fieldwork, the silvopastoral program was in its fourth year of operation. Similar to the experiences of PROFAFOR, in its first several years, the program and participants had to reconcile with context specific ecological and economic conditions. First, the original tree species used for the live fences and the fodder species did not grow well. In addition, program officers questioned the economic and social viability of the program. Although extension agents documented increases in milk production, participants did not necessarily perceive a direct relationship between improved pasture management and increased dairy production, and most were not making the investments needed to sustain the silvopastoral practices. Program officers also recognized that the profits from milk production were limited due to the farmers' reliance on a middle man for selling their milk.

Participant response to the challenges of implementing the silvopastoral practices was largely dependent on FN. Although the majority of participants (70 %) identified improved pasture lands as their top household need, and 90 % believed that the silvopastoral practices could improve their pasture lands, few participants took actions to maintain the silvopastoral practices in response to ecological and economic challenges. In response to the initial problems with the tree species and fodder banks, only two of the original 23 farmers had replanted using local species, despite several farmers mentioning that they knew where to obtain suitable species. Furthermore, when asked whether they would continue with the silvopastoral techniques, almost all of the original participants stated that they would maintain the live-fences, but only 41 % stated that they would continue to fertilize their fields, an important component of sustained pasture management. Many commented that in addition to financial resources, they needed technical assistance to motivate them to continue to invest in the silvopastoral practices.

FN program managers and extension agents did, however, make programmatic changes based on new ecological and socio-economic information. In order to improve the tree species, program officers explained that FN sought out tree nurseries in the region, and worked to establish their own nurseries directly in the communities to increase the supply of seedlings and to serve as learning venues. The community nurseries were intended to serve as field sites for residents, students, and other local organizations to learn and experiment on the development of successful native species for agroforestry practices (Giraldo et al. 2012).

In response to the economic viability of the silvopastoral practices, FN and associates were working to start a dairy cooperative in the communities. Program officers stated that the goal of the cooperative was to eliminate the middle-men so that the dairy production, transportation, and sale would be controlled by farmers in the region. The farmers had previously worked to organize their own dairy, but it had ultimately failed. According to FN program officer Peñaloza (2012), although the farmers generally supported the idea of starting a cooperative, it had been a struggle to organize them.

Despite some of these challenges, participants continued to express interest in the program. In interviews, FN extension agents noted that they now had more applicants than they could realistically serve. FN participants generally favored the use of the conditional contracts. 80 % considered the contracts to be legitimate, with several commenting that it gave the conservation activities more teeth. Furthermore, in the negotiation process for the next set of contracts, FN responded to participant demands for greater commitment to forest conservation, by extending the contracts (but not the payments), from 3 to 5 years.

Discussion

Synthesis of Findings: Comparison of Two PES Models in the Context of Adaptive Decision-Making

In their characterization of PES programs, Engel and colleagues (2008) suggest that the design and outcomes from PES programs is highly dependent on who took the initiative to create and implement the program. Similar to many PES programs across the Global South (Engel et al. 2008; Wunder 2013), the programs in Ecuador and Colombia were initiated by an external buyer, and associated intermediary. While both cases demonstrate the potential incompatibility between conditional contracts and sustainable resource management, the carbon offset program in Ecuador highlights the ways in which "user-financed" programs, particularly those aimed at a competitive futures market such as carbon, may be particularly challenged to act as tools for adaptive decision-making.

In Ecuador, the PES institutions were designed to support the buyers' goal of long-term verified carbon credits for an international market, irrespective of changes in local social, economic, and ecological conditions. Thus, the incentive system was based on the expected financial profits to be gained at the end of the contract period, and dependent upon successful maintenance of the plantations. PROFAFOR's information gathering focused on analyses

of expected prices for carbon credits, timber profits, and implementation costs, and on monitoring for compliance with pine management practices. Land management decisions and contract conditions, likewise, aimed to ensure the long-term provision of carbon offsets.

Although the program design successfully ensured the provision of carbon offsets to the international carbon market, it did little to promote adaptive decision-making and sustained resource management in response to local conditions. For both, participants and PROFAFOR, the most significant challenge was adapting to less than expected economic benefits from the pine plantations. Similar to findings from other studies of PROFAFOR (Milne and Arroyo 2003; Albán and Argüello 2004), farmers in Nabón planted pine because they perceived timber to be profitable crop for their lands. These profits, however, depended upon the production of healthy trees and a strong local market for the timber. In a similar economic vein, PROFAFOR, promoted the plantations with the expectation of economic gains from the sale of carbon offsets. As the PROFAFOR director explained, the ability to cover PROFAFOR's operation costs depended upon financial profits from the sale of the carbon offsets.

The ability of participants and PROFAFOR to respond to poor tree conditions and low market prices was limited in part by information, but largely by a lack of decision-making rights. Faced with new familial pressures and uncertain profits from the plantations, some farmers expressed motivation to change their land-use practices. PROFAFOR also recognized that many of the plantations were failing. The contract conditions and the commitment of future carbon offsets sold in the carbon market prohibited PROFAFOR and the farmers from changing the pine management activities for at least 20 years. Ultimately, PROFAFOR decided that the best option was to discontinue the program. PROFAFOR has expanded its portfolio to provide more profitable services; the farmers remain obligated to maintain their plantations for the duration of their contracts.

In contrast to the PROFAFOR "user-financed" model, the silvopastoral program in Colombia followed a "government-financed" model in which donors sought to pay for the provision of a more localized environmental service (regional watershed protection) irrespective of an actual market for that service. In designing the program, while FN was beholden to the donors to demonstrate gains in forest conservation and reforestation, the organization had greater leeway than PROFAFOR to engage with the farmers in defining land-use practices and contract conditions.

The result was a program that facilitated greater opportunities for learning and adaptive decision-making on the part of the participants and the program officers. Although FN monitored for compliance with the program objectives and assessed the ecological impacts of the conservation measures, the program used more participatory learning processes to involve farmers with the silvopastoral practices. FN helped organize farmer-to-farmer fieldtrips where the farmers could share their experiences, and program technicians visited the participants regularly. Likewise, participants specified some of the contract conditions and worked with technicians to decide the day-to-day management practices on their farms.

The program has nonetheless, met with challenges. Program officers have learned and adapted the program design and management practices in accordance with changing conditions, however, the program has struggled to motivate farmers to experiment and adjust their silvopastoral management practices accordingly. Farmers recognized that the initial tree species were failing and many knew of local species that they considered better suited to act as live fences, nonetheless very few farmers took the initiative to replant the trees. Although milk production is a principal source of income for these households, the farmers were not actively monitoring how much their milk production had changed since using improved pasture management techniques, nor were they willing to invest their own resources to sustain the silvopasture techniques.

FN, however, has maintained an adaptive approach to the program. The short time frame of the contracts, work to monitor the environmental and social impacts of the program, and the consistent presence of FN in the region enabled program officers to assess current program practices, get participant input on the contract terms and practices, and make changes before renewing the contracts or starting with new participants. The change in tree species and development of local native tree plantations, efforts to develop a dairy cooperative and the change in contractual duration from 3 to 5 years all speak to the efforts and capacity of FN to learn and adjust program protocols given changing conditions.

Challenges and Opportunities for Incorporating Adaptive Decision-Making into PES

While limited in their generalizability, the findings from Ecuador and Colombia, and the literature on sustainable development, suggest several challenges that PES must contend with as a tool for flexible and adaptive resource management. Such challenges include: (i) the use of direct incentives and conditional contracts to motivate sustained resource management, (ii) limited information sharing between sellers, intermediaries, and buyers, and a narrow focus on monitoring for compliance, and (iii) the restricted capacity of participants and program officers to make and modify resource management rules in response to changes in local conditions.

Incentive Structure

The findings from Ecuador and Colombia buttress the concerns expressed by other scholars of payment programs (Hellin and Schrader 2003; Clements et al. 2010; Vatn 2010), regarding the ability of direct incentives and conditional contracts to motivate farmers to sustain conservation measures. Many PES proponents argue that the use of conditional incentives distinguishes PES from previous conservation and development projects and makes PES a more efficient tool for resource management. In both Ecuador and Colombia, while the economic incentive served to initiate behavioral change, it did not motivate, and most likely hindered, resource managers' initiative to sustain those practices, as participants' management activities depended upon receiving a payment. In Ecuador, even though the economic viability of the farmers' plantations depended on maintenance practices, several farmers stated that they had not pruned their trees because PROFAFOR had not provided sufficient funds to cover the costs. In a similar vein in Colombia, participants often stated that they were to "care for" the materials given to them by FN, but took little initiative to maintain the silvopastoral practices. Many (48 %) stated that they were unlikely to sustain the practices without the continued provision of financial and technical support.

The lack of participant motivation to sustain new management practices is not unique to PES and is a challenge for many agricultural adoption and natural resource management programs (Bunch 1999; Giger 1999; Vatn 2010). In resource management, however, the use of direct incentives and external experts has long been critiqued for decreasing the likelihood that resource users will perceive themselves to be capable of innovating, experimenting, and making appropriate resource management decisions (Bunch 1999; Giger 1999; Hellin and Schrader 2003; Clements et al. 2010; Vatn 2010). While more recent research suggests that the impact of incentives is complex and may vary depending on the institutional design of the PES system, the incentive structure, and previously existing land-use norms and values (Van Hecken and Bastiaensen 2010; Narloch et al. 2012; Wunder 2013), further research is needed to systematically assess how contracts and incentives impact participant's motivation and perceived capacity to adaptively manage their resources.

Limited Information Exchange Mechanisms

The case studies illustrate the challenges of crafting management practices in complex social-ecological systems, and the need for more inclusive and iterative approaches to information exchange between the buyer, the seller, and the respective intermediaries. Specifically, two concerns emerge from the experiences in Ecuador and Colombia. First, is the ability of PES programs to support two-way sharing between participants and program officers regarding local knowledge of ecosystem functioning and feedback on the impact of PES management rules. An additional, and more complicated concern, is the tendency of PES to focus program monitoring on environmental service benefits narrowly defined by the buyer.

With regards to the first concern, the FN silvopastoral program illustrates several ways in which participants may be included in sharing information on the program techniques and their application. The farmer-to-farmer exchanges, dairy logs, and community tree nurseries are examples of fairly simple participatory learning methods. FN was weaker in its initial inclusion of participants in the design of the silvopastoral practices and monitoring of the ecological impacts. Work in agricultural adoption offers various participatory research methods that can easily be incorporated into PES programs to support participation in the design and monitoring of resource management activities (for other approaches see Chambers et al. 1989; Ashby and Sperling 1995; Braun 2000; Godtland et al. 2004; Holt-Gimenez 2006).

The second concern, failure to monitor the broader impacts of PES practices, may be a more difficult challenge for PES programs to address. The carbon offsets program in Ecuador is particularly illustrative of the need for long-term monitoring of social, economic, and ecological impacts. As discussed, information exchange mechanisms between the participants, PROFAFOR, and the buyers was limited, and ultimately, the program was not able to adapt management practices to fit local ecological and socio-economic conditions. Furthermore, program information gathering focused on an initial analysis of the economic viability of pine plantations, but monitoring focused on plantation maintenance to ensure long-term verified carbon credits for the buyer. It is interesting to note that an initial study of the PROFAFOR carbon offsets program estimated that the program would have a positive economic impact on the participants (Wunder and Albán 2008).

A study by Albán and Argüello (2004), however, cautioned that the impact of the pine plantations could extend into the social and economic dynamics of the communities. The authors found that participants may rely more or less heavily on their highlands for grazing, fuel wood, construction materials, and agricultural lands depending on changing demographics and economic conditions. Given that the pine plantations replaced these other land-use benefits; the authors recommended greater long-term monitoring of the social and economic impacts of the pine.

The concerns expressed by Albán and Argüello regarding the impacts of PES management practices echo those of ecologists working in high-montane systems who

emphasize the uncertainty involved in the functioning of said ecosystems, and who stress the need to treat management practices as experiments (Celleri and Feyen 2009; Crespo et al. 2011). Covering the costs to implement broader long-term monitoring of PES impacts may, however, be beyond the scope of a buyer who is primarily interested in the provision of a specific ecosystem service.

Rule-Making Rights and Flexibility Mechanisms

Ultimately, one of the greatest challenges for PES programs may be their limited capacity to incorporate local decision-making and flexibility into current and future resource-use decisions. Ideally, PES arrangements would be completely voluntary and negotiated agreements in which the buyer and the seller mutually agree upon the contract terms. However, as exemplified by experiences in Ecuador and Colombia, the buyers or intermediaries often initiate the program, decide the ecosystem service to be provided, and determine and implement the terms by which they will attain those services, often over extended time frames (Wunder 2013). If a resource-user decides to participate, in many cases, the user grants all current and future management rights to the buyer.

The restriction of management rights is problematic first, because rule-making is often granted to a buyer, or their respective intermediary, whose livelihoods may not depend on how the local social-ecological system functions. In many cases, the intermediaries' income may depend heavily on supplying an ecosystem service in response to buyers' demands, and not necessarily to local conditions. Such was the case of PROFAFOR as the buyer's demand for carbon offsets determined the pine plantation contracts in Ecuador. Albeit to a lesser extent, donor demands also prescribed the monitoring mechanisms used by FN to demonstrate success.

Second, the time frame of these management restrictions is problematic. PES programs, particularly for carbon sequestration, often extend for periods that may go beyond a participant's life time. In Ecuador, in addition to PROFAFOR contracts, the government has established conditional contracts for forest conservation for 20 years (de Koning et al. 2011) and for watershed management for indefinite periods (Wunder and Albán 2008). In Mozambique, farmers signed 100 year contracts to provide carbon offsets (Jindal et al. 2012).

The ability of local resource users to make and modify management rules in accordance with local conditions is a predominant theme in Ostrom's design principals. Theoretical and empirical findings consistently caution against absentee land managers (be they governments or private individuals) as research suggests that local resource managers that hold decision-making rights, design rules that are more sensitive to local conditions and are often more responsive to changing management needs (Bromley and Cernea 1989; Bromley 1992; Cardenas et al. 2000; Ostrom 1990, 2003; Gibson et al. 2000; Armitage 2005; Hayes and Ostrom 2005; Persha et al. 2011).

The use of long-term contracts demands a high degree of certainty involved in managing complex social-ecological systems; certainty that neither program designers nor participants most likely have. Both studies illustrated that we lack a strong understanding of the ecological dynamics of South American ecosystems, particularly highland systems (Celleri and Feyen 2009; Crespo et al. 2011). Furthermore, the socioeconomic dynamics in these systems are complex and difficult to predict. In their study of PROFAFOR, Albán and Argüello (2004) found that participants had difficulties envisioning future land-use needs. In our interviews, a PROFAFOR participant noted that when he signed the contract his son was young and he did not think about future land-use needs of his son's family. As in many long-term PES scenarios, future generations may still own the land, but they will not have agreed to the contract terms, and may not receive any economic compensation for the ecosystem services (Jindal et al. 2012).

A number of PES programs offer examples of ways in which participants may be incorporated into the creation of the contracts and the day-to-day management conditions. In Colombia, the conservation organization RARE has crafted watershed conservation agreements by holding community forums in which the sellers (smallholder farmers) negotiate with the municipality to decide the practices that they will implement and the incentives that they will receive for watershed conservation (RARE employee, personal communication, August 2010).

Increased participation may, however, increase the transaction costs in coming to an agreement between the buyer and the seller. Several programs, including FN, have opted to offer sellers a portfolio of land-use options that they can select from. For example, the Plan Vivo Standard created by the Plan Vivo Foundation provides a framework for organizations who wish to work with communities to determine their conservation priorities, and identify how a carbon project would integrate with local social, economic, and natural systems. Communities and individuals may select from a variety of land-use options that include agroforestry, reforestation, and afforestation with native or naturalized species, and forest conservation activities. Individuals and communities sign contracts for a minimum of 10 years (Plan Vivo Standard 2013).

Plan Vivo projects have been implemented around the world and several scholars have reviewed Plan Vivo (Corbera et al. 2007a, b; Dougill et al. 2012; Jindal et al. 2012). While there are concerns regarding the ability to fully apply the standards and ensure that participants are

involved in the planning and implementation process (Dougill et al. 2012), Plan Vivo provides a structure that supports broader information and monitoring requirements, and offers participants greater decision-making rights regarding the land-uses they choose to abide by for contract duration.

The contract duration, however, remains a challenge for PES as a flexible resource management tool. The experiences from Colombia and Ecuador suggest that short-term contracts may be more appropriate for managing complex social-ecological systems. Given the demand for long-term verified carbon credits and current carbon prices, however, shorter term contracts in carbon offset programs may not be economically feasible (Jindal et al. 2012). Nonetheless, long-term contracts may be asking resource managers to commit to land-use practices that are socially, economically, or ecologically unsustainable.

Conclusion

The above mentioned concerns are not new to resource management and have been well-documented in the conservation and development literature. The goal of this paper is to encourage PES proponents to critically assess how PES programs might learn from previous experiences in conservation and development, and gain insights from work in adaptive decision-making. The experiences in Ecuador and Colombia illustrate some of the challenges that PES faces as a tool for flexible and adaptive management.

First, the findings highlight the need for PES programs to systematically assess how incentives and conditional contracts influence the motivation and capacity of resource users to manage their resource systems according to changing social and ecological conditions. Furthermore, if PES is to function in complex and dynamic social-ecological systems, PES programs need to recognize the degree of uncertainty associated with the proposed management practices. Including greater participation from local resource users in the planning and monitoring of management practices is one means to address this uncertainty and encourage resource users to engage in the management activities. A broader set of social, economic, and ecological outcomes should also be monitored.

Ultimately, however, PES programs need to be able to respond to these feedback and monitoring mechanisms. One of the greatest limitations of PES as a flexible management tool is the restricted ability of resource users and program officers to modify existing resource-use rules. The results from the carbon offset program in Ecuador suggest that user-financed systems that depend on a futures market, such as carbon sequestration, may be particularly ill-suited to address changing social and ecological conditions. The limitations of the carbon market are important in considering the institutional design and implementation of future carbon sequestration programs, such as REDD+. While such programs may be able to include greater participation in the selection of the initial set of resource-use practices and monitoring of the impacts, the length of time that participants may need to commit to a particular set of land-use practices inherently restricts local responses to changing conditions or resource use priorities, potentially impeding sustained resource management.

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